

Evaluating the Effects of Human Development Patterns on Terrestrial Wildlife Habitat Function

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Abstract

To inform the process of local land-use planning in the Chico Creek Watershed 3 future development scenarios (Planned Trend, Conservation, and Moderate alternatives) were evaluated for their effects on terrestrial wildlife habitat. Land cover was mapped from existing sources; 12 land-cover and 4 stream-channel classes were used to depict habitat conditions in the watershed. Future landscape condition was modeled by assigning “footprints” to undeveloped parcels based on zoning density and lot size. Assumptions focused on how land use patterns affect forest age. Wildlife-habitat relationship models were constructed for 9 species: the red-legged frog, western toad, Douglas’ squirrel, bobcat, downy woodpecker, pileated woodpecker, willow flycatcher, blue grouse, and great blue heron. Habitat quality was evaluated based on vegetation type, patch configuration, and home-range size. Species models were run on current and future land covers. Landscape changes that applied to nearly all species under all future alternatives regardless of habitat association include: (1) a decrease in the total amount of habitat available; (2) an increase in fragmentation (i.e. an increase in the number of patches with a corresponding decrease in patch size; and (3) a decrease in habitat quality resulting from loss of primary breeding and foraging habitat. Landscape changes under the Conservation scenario were intermediate between current conditions and the Planned Trend. The Moderate scenario maintained large blocks of land and wildlife corridors to mitigate the effects of Planned Trend development.

Under Washington’s Growth Management Act (RCW 36.70A), counties and cities are required to cooperate with other government agencies, local businesses, and private citizens to develop comprehensive land use plans. In Kitsap County, Washington, local officials decided to test the alternative futures process (Hulse et al. 2000; Steinitz 1997) in the arena of community planning, which occurs at the watershed scale. The Chico Creek Watershed was chosen for this pilot effort because of its high natural resource values and its proximity to more urbanized areas. Primary land uses are rural residential and forestry; development pressure from the surrounding area may conflict with traditional land use. The aim of the Chico Creek Alternative Futures project was to use science and citizen participation to inform the process of local land use planning by examining the effects of three future development scenarios on natural resources. The Kitsap County Board of Commissioners called upon local citizen’s to become educated in issues related to natural resources and land use planning in order to design their own future development alternatives. The expectation was to create a plan that balanced sound stewardship of natural resources with the Growth Management Act and other planning requirements to develop a predictable pattern for growth and development that did not sacrifice the character of the community (see KCD CD 2003 for more detail). Future scenarios included (1) the Planned Trend (i.e. full build out of the Kitsap County Comprehensive Plan, adopted May 7, 1998); (2) a Conservation scenario; and (3) a Moderate scenario. The Watershed Advisory Committee (WAC; the citizens) outlined the parameters for the Conservation and Moderate scenarios, which were used by the Technical Working Group (TWG; the scientists) in their analyses of potential effects. The 3 future alternatives were evaluated with respect to their influence on water quality, water quantity, hydrology, and aquatic and terrestrial habitat function (see Nelson 2003a; Nelson 2003b; Roberts 2003; Segura-Sossa et al. 2003). This paper addresses the influence of human development patterns on wildlife habitat.

Habitat loss, fragmentation, and degradation are consequences of expanding human populations that can have profound effects on wildlife populations (Czech and Krausman 1997; Dobson et al. 1997). The quantity and quality of wildlife habitat on the Kitsap Peninsula has changed dramatically since European settlement. The diverse composition and structure of old growth conifer forests has been replaced by even-aged monotypic stands of small trees, houses, roads, and commercial structures. Species whose historical distribution did or likely included the Kitsap Peninsula are the marbled murrelet (*Brachyramphus marmoratus*), spotted owl (*Strix occidentalis*), northern goshawk (*Accipiter gentilis*), fisher (*Martes pennanati*), gray wolf (*Canis lupus*), elk, western pond turtle (*Clemmys marmorata*), and common loon (*Gavia immer*) (K. Aubrey, USFS Pacific Northwest Research Station, pers. comm.; Harpole and Lyman 1999; Hays et al. 1999; Jewett et al. 1953; Johnson and Cassidy 1997; Richardson et al. 2000; Smith et al. 1997). Species whose status has declined or is uncertain include the peregrine falcon (*Falco peregrinus*) and merlin (*Falco columbarius*). Species most susceptible to extinction and degradation often exhibit the following characteristics: specific habitat requirements, limited geographic distribution, low reproductive rates, and high trophic position (Gilpin and Soule 1986; Rabinowitz 1981). We assessed the effects of human development patterns on wildlife habitat in Chico Creek by

modeling residential development along with vegetation change for each future scenario. Species habitat relationship models for 9 terrestrial wildlife species built on these land cover changes were used to evaluate how changes in habitat conditions at the landscape scale influence habitat suitability at the home range scale. We compared our results among scenarios and to current conditions to gauge future trends. The WAC will consider this information along with data on other natural resource impacts. WAC will in turn make recommendations to the residents of Chico Creek and the local planning commission with the intention of implementing a sub-area plan that balances natural resource extraction, urban development, and healthy ecosystem function.

Methods

The Chico Creek Watershed is located 2 m (3 km) west of the city of Bremerton on the Kitsap Peninsula in western Washington. It is approximately 10,432 ac (4,222 ha) in size and stretches from Green Mountain in the west to Dyes Inlet in the east and from the Bremerton Municipal Watershed in the south to Camp Wesley Harris Naval Reservation in the north. It has a wet, mild, maritime climate with precipitation ranging from 45-65 in/yr (110-170 cm/yr) across an elevational gradient (Roberts 2003). Chico Creek has 4 major tributaries: Kitsap, Lost, Dickerson, and Wildcat Creeks. Collectively these streams run 68 mi (109 km), draining into Puget Sound opposite the city of Seattle (KCD CD 2003). The vegetation is characteristic of the western hemlock zone (*Tsuga heterophylla*) and consists primarily of Douglas-fir (*Pseudotsuga menziesii*), western hemlock, and red cedar (*Thuja plicata*), which mix with red alder (*Alnus rubra*) and big-leaf maple (*Acer macrophyllum*) in mesic areas (Franklin and Dyrness 1973). Common understory plants include salal (*Gaultheria shallon*), Pacific rhododendron (*Rhododendron macrophyllum*), huckleberry (*Vaccinium* spp.), salmonberry (*Rubus spectabilis*), and vine maple (*Acer circinatum*).

Land use/land cover. To assess present conditions for wildlife in the Chico Creek Watershed we developed a current land cover map from existing land cover data, airborne imagery, and cartographic data sources. The primary land cover data, derived from the Interagency Vegetation Mapping Project and the National Land Cover Data, provided a ready-made base data set from which we could build and refine the Chico land cover map. Recent forest harvest activity was mapped using satellite remote sensing change detection techniques over the 1996 to 2000 time period. Airborne Light Detection and Ranging (LIDAR) digital imagery provided broad tree and shrub height information for discriminating between low and high canopy. Airborne multi-spectral scanner data, flown in 2000, provided additional large-scale land cover information. Hydrographic information was derived from 1:24,000-scale cartographic data depicting stream location and gradient. Wetland polygons were derived from multiple sources including National Wetlands Inventory, Washington Department of Natural Resources 1:24,000-scale wetlands data, and from the federal land cover data sets. A total of 12 land cover and 4 stream channel classes (Table 1) were created and mapped for the current conditions model using a 25-m pixel size. The final land cover map extends 5,437 ft (1,657 m; radius of a pileated woodpecker home range) past the watershed boundary to account for adjacent land cover change that could alter the suitability of habitat within the watershed. The total area of our analysis covered 25,255 ac (10,221 ha). The map was field-checked for general accuracy.

Future Landscapes. To model future development patterns we applied critical areas specifications, zoning designations, and land use assumptions from each future alternative to the current land cover. Future development was simulated by (1) classifying urban, commercial, industrial, and right-of-way zones as Fully Developed (Table 1); (2) placing a square "footprint" (i.e. impervious surface, turf, and bare ground) equal to 35% of the parcel size on each undeveloped lot in land use zones with a minimum designation of 1 dwelling unit (du) per ac.; and (3) overlaying critical areas (riparian areas and wetlands) on new footprints; footprints were reduced as a result of overlap to preserve critical areas and their buffers. Where parcels were larger than the designated zoning the correct number of footprints was randomly placed throughout the parcel. The footprint was classified as Fully Developed. Average footprint size was estimated using 2002 land cover (Kitsap County GIS Department) and tax assessment data (Kitsap County Assessors Office) on parcels with building values >\$20,000. Buildings valued at <\$20,000 were assumed to be non-residential. The average footprint size was determined by a regression equation: footprint area = $b + m * \text{parcel size}$ (Fig. 1; b = y-intercept; m = slope of regression line); regressions were run separately for each land use zone (e.g., Interim Rural Forest, Rural Residential, etc.). Values for b and m varied by land use zone and values for r^2 ranged from 0.47-0.65 (Zar 1996). Footprints averaged 35% of lot size (range 28-41%). For lots >40 ac we set a maximum footprint size equal to that of a 40-acre parcel. We assumed that parcels with building values >\$20,000 were already developed.

Table 1. Habitat classification scheme for land cover and stream channel classes modeled in the Chico Creek Watershed in Kitsap County, Washington. Age of stands is approximate based on timber management rotations (B. McKinney, City of Bremerton, pers. comm.), incidental tree ring counts, and site class data (King 1966); dbh = diameter-at-breast-height.

Habitat Classification		Vegetation type
1	Mature Conifer	Conifer cover $\geq 70\%$ AND $\geq 10\%$ of canopy in trees $\geq 21''$ dbh; age > 70 yrs old
2	Young Conifer	Conifer cover $\geq 70\%$ AND $\leq 10\%$ of canopy in trees $\geq 21''$ dbh; age 25-70 yrs old
3	Low Mixed Conifer/Deciduous	Canopy height $< 50'$ AND Conifer cover 40-69% and any deciduous cover OR Deciduous cover $> 40\%$; age 15-25 yrs old
4	Tall Mixed Conifer/Deciduous	Canopy height $\geq 50'$ AND Conifer cover 40-69% and any deciduous cover OR Deciduous cover $> 40\%$; age > 40 yrs old
5	Grass/Forb/Bare	Conifer cover $< 40\%$ AND Deciduous cover $\leq 40\%$; age 0-15 yrs old
6	Wetland	Freshwater marsh/wetland
7	Salt Marsh	
9	Agriculture	Includes pasture, row crops, fallow, and some orchards
10	Fully Developed	Residential/Commercial/Transportation; all development
11	Lakes, Ponds	Fresh water
12	Marine Water	
16	Double Bank Stream	River mainstem
51-55	Stream/Channel: Gradient 0-10%	Add feature to upland class in stream channel
101-105	Stream/Channel: Gradient 11-20%	Add feature to upland class in stream channel
151-155	Stream/Channel: Gradient 21+ %	Add feature to upland class in stream channel
99	Far-shore Marine Water	More that 820 feet from shore

Current forest management practices were used to shape future landscape conditions within the constraints of each future alternative. We created polygons based on natural features (i.e., forest stands) by smoothing the land cover grid and intersecting it with sub-watershed boundaries and topographic aspect. Land zoned as Open Space (e.g. Mountaineers property) progressed to mature conifer or if currently classified as tall mixed, then no change was made. We assumed tall mixed forest was in a semi-climax state reflecting site characteristics. On the Bremerton Municipal Watershed we assumed stream protection guidelines greater than the Forest and Fish Rules (WAC-222), a selection-cut harvest, 60-80-yr rotation, and designated no-harvest areas based on current management practices (B. McKinney, City of Bremerton, pers. comm.).

Zoning designations from the Kitsap County Comprehensive Plan were used to model the Planned Trend. We assumed that lots < 10 ac would not be managed for timber and that habitat patches would age to mature conifer unless they were classified as tall mixed or grass/forb/bare/forb habitat, in which case we assumed no change (Table 2). Grass/forb/bare was assumed to be lawn or pasture; this assumption changed under subsequent alternatives. Undeveloped lots from 10 to 40 ac were randomly designated “harvest” or “no harvest” in equal proportions, based on current trends observed by local foresters (P. Nelson, Kitsap County, pers. comm.). “No harvest” lots remained tall mixed-forest or became mature conifer forest. “Harvest” lots were randomly designated grass/forb/bare, low mixed forest, or mid/early conifer forest by assuming a 60-yr rotation and even-age distribution. This approach produces a time-independent model that assumes harvest is occurring at a sustainable rate. Maximum lot size was 40 ac as per current zoning; this assumes that Washington Department of Natural Resources (DNR) lands in the southwest part of the watershed would be developed and/or sold.

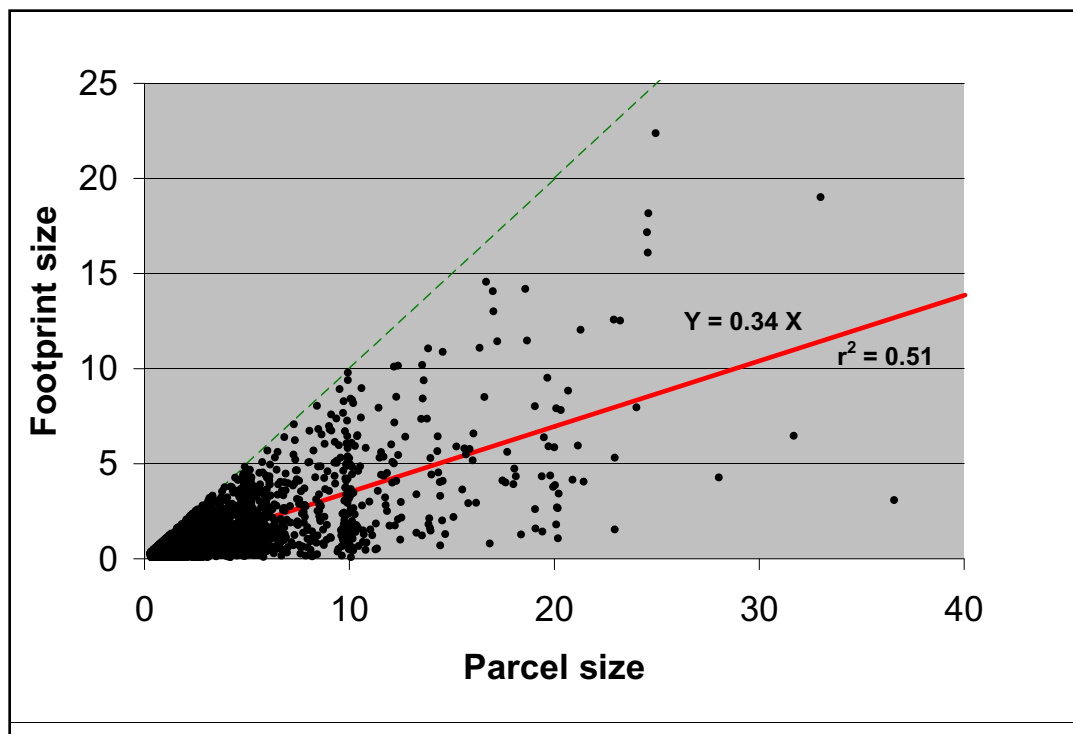


Figure 1. Regression of footprint size against parcel size for lots with building values >\$20,000 in Kitsap County, Washington. This example, from the Rural Protection zone, typifies regressions run for each rural land use zone. Data were derived from 2002 Kitsap County land cover and tax assessment data.

The Conservation and Moderate scenarios applied critical areas specifications, zoning designations, and land use assumptions developed cooperatively by WAC and county staff. In the Interim Rural Forest and Forest Resources zones parcels were aggregated by ownership. One dwelling unit was allocated to each landowner block, including DNR lands; remaining lands were managed for timber (Table 2). Other land management assumptions were similar to the Planned Trend scenario.

The Moderate scenario reduced development effects by partial transfer of development away from 2 important areas (1) the Interim Rural Forest and Forest Resources zones, and (2) within specified portions of two designated wildlife corridors (KCDCD 2003). Development within the forest zones was randomly placed; parcels were developed in only small portions of the wildlife corridors (KCDCD 2003). Development rights were transferred to: (1) the LAMIRD (Limited Area of More Intense Rural Development) or (2) Rural High Density zone, which were developed at 1dwelling unit/2.5 ac.

Species models. Species-habitat models were constructed for 9 terrestrial vertebrates to assess the effects of land cover change between future scenarios and current conditions. The species modeled were the red-legged frog (*Rana aurora*), western toad (*Bufo boreas*), Douglas' squirrel (*Tamiasciurus douglasii*), bobcat (*Lynx rufus*), pileated woodpecker (*Dryocopus pileatus*), downy woodpecker (*Picoides pubescens*), willow flycatcher (*Empidonax traillii*), blue grouse (*Dendragapus obscurus*), and great blue heron (*Ardea herodias*). A species was chosen for at least one of the following reasons, it: (1) was a species of concern;; (2) was a target species for the Puget Trough ecoregional assessment (Groves et al. 2002); (3) uses habitat(s) that would be likely to change under future management conditions; and /or (4) has a large area need and may be sensitive to habitat loss. All species are native to western Washington and were known or expected to occur in the Chico Creek Watershed based on available information.

Table 2. Assumptions used to model forest cover under three future landscape alternatives for the Chico Creek Watershed, Kitsap County, Washington. Fully Developed refers to parcels with an existing structure. Riparian refers to the source of buffers applied to lakes, streams, and wetlands; DNR = Washington Department of Natural Resources; du = dwelling unit.

Current zone/lot size	Planned Trend	Conservation	Moderate
Suburban/rural			
<10 ac developed	No harvest: outcome A ^a	Same	Same
<10 ac undeveloped	No harvest: outcome B ^b	Same	Same
10-40 ac developed	No change ^c	50%:No harvest: outcome B ^b 50%: 55-yr timber rotation; Even-age distribution Riparian: Forest and Fish ^e	50%:No harvest: outcome B ^b 50%: 55-yr timber rotation; Even-age distribution Riparian: Forest and Fish ^e
10-40 ac undeveloped	50%:No harvest: outcome B ^b 50%: 60-yr timber rotation; Even-age distribution Riparian: Kitsap CAO ^d	Same 50%: 55-yr timber rotation; Even-age distribution Riparian: Forest and Fish ^e	Same 50%: 55-yr timber rotation; Even-age distribution Riparian: Forest and Fish ^e
>40 ac	Not applicable	100%:55-yr timber rotation; Even-age distribution Riparian: Forest and Fish ^e	100%:55-yr timber rotation; Even-age distribution Riparian: Forest and Fish ^e
Interim Rural Forest	As above	1 du/ownership block	~ 33% developed @ 1 du/20 ac; 66% undeveloped
Forest Resource	As above; includes DNR land	1 du/ownership block; includes DNR land	~ 33% developed @ 1 du/40 ac; DNR land undeveloped

^a Outcome A: trees progress to mature conifer, OR if tall mixed forest, or grass/forb/bare then no change.

^b Outcome B: trees progress to mature conifer, OR if tall mixed forest then no change.

^c Lots assumed to reflect landowners desire; few lots here; assumption abandoned for Conservation and Moderate scenarios.

^d Kitsap County Critical Areas Ordinance buffers: Type 1, 2 and 3 = 200'; Type 4 = 50'; Type 5 = 25'; lakes = 35'; Type 1 wetlands = 200'; Type 2 wetlands = 100'; Type 3 wetlands = 50'; Type 4 wetlands = 25'.

^e 2002 DNR Forest and Fish buffers: Type F streams = 105' each side; Type NP streams = 50' each side; lake = 105'; large wetland = 100'; small wetland = 50'.

Species-habitat relationships and distributions were modeled using HABSCAPES Version 2.0, developed by Mellen et al. (2001) for landscape-scale analysis on the Mt. Hood National Forest in Oregon. HABSCAPES evaluates terrestrial habitat quality based on vegetation type, patch configuration, and home-range size. HABSCAPES assigns a value to each pixel using a nearest-neighbor analysis of habitat types designated as suitable. Pixels are grouped by a set of user-specified decision rules that guide the initiation of patches and when and how pixels and patches are joined. Moving windows analyses are conducted at two scales to assess habitat quality: (1) the minimum patch size; and (2) the home-range size. Patches are ranked according to their size, juxtaposition, and contribution to specified area needs within the vicinity of the home range circle. The program offers different models depending on whether (1) a species needs more than one habitat to meet their life history requirements (e.g., great blue heron), or (2) requirements can be met in a single habitat (e.g., downy woodpecker).

Modeling parameters were assembled from peer-reviewed literature and expert opinion (Table 3). Models included all habitats with which a species had breeding and foraging associations; resting habitat was added where it differed from breeding and foraging habitats (Brown 1985). We assumed that habitat classified as Fully Developed was of limited value to most wildlife species and was not included in species models, although appropriate-sized habitat patches within urban areas were included. We assumed that habitat classified as Fully Developed would not become habitat in the future.

Habitat maps were produced for each species based on current conditions and the 3 future land cover scenarios. Habitat patches were grouped according to their ability to contribute to a species' home-range requirements; cover types not used by a species were considered unsuitable. The amount and distribution of vegetation types was examined across land cover models to look for changes in the availability of habitat. We compared the quantity and quality of habitat patches between current conditions and future landscapes to assess potential impacts to individual species at the home range and landscape scales.

Table 3. Parameters used to model species-habitat relationships. Habitat numbers refer to habitat types in Table 1. Minimum patch indicates smallest-sized patch a species would be expected to use; 1.0 ac (0.4 ha) is the minimum allowed by HABSCAPES. Model C = contrast: >1 habitat may be needed to meet life history needs; S = suitable: 1 habitat may meet all life history needs. Data from Aubry (1997); Brown (1985); Johnson and O'Neil (2001); G. Koehler, Washington Department of Fish and Wildlife pers. comm.; C. Raley, USFS Pacific Northwest Research Station, pers. comm.; Runde et al. (1999); Yengoyan (1995).

Species	Model	Habitat	Minimum patch ac (ha)	Home range ac (ha)	Ranging distance m ^a
Douglas' squirrel	S	1-4, 6, 51-54, 101-104, 151-154	1.0 (0.4)	3.0 (1.2)	na
Blue grouse	C	Forest: 1, 2, 4, 51, 52, 54 Field: 3, 5, 53, 55	1.0 (0.4)	48.0 (19.4)	F to Fi: 2000 Fi to F: 90
Bobcat	S	1-7, 51-55, 101-105, 151-155	40.0 (16.2)	2829.0 (1140.8)	na
Willow flycatcher	S	3, 5, 6, 53, 55, 103, 105, 153, 155	1.0 (0.4)	3.0 (1.2)	na
Downy woodpecker	S	3, 4, 6, 53, 54, 103, 104, 153, 154	5.0 (2.0)	16.0 /pair (6.5)	na
Pileated woodpecker	C	Forage: 2, 52, 102, 152 Breed: 1, 4, 6, 51, 54, 101, 104, 151, 154	F: 12.0 (4.9) B: 40.0 (16.2)	2132.0/pair (862.8)	1657
Red-legged frog	C	Forage: 1, 2, 4, 5 Breed: 6, 11, 16, 51, 52, 54, 55	1.0 (0.4)	12.0 (4.9)	F to B: 500 B to F: 200
Western toad	C	Forage: 1, 2, 3, 4, 5 Breed: 6, 11, 16, 51-55	1.0 (0.4)	67.0 (27.1)	F to B: 1000 B to F: 200
Great blue heron	C	Forage: 6, 7, 11, 12, 16 Breed: 1, 4, 51, 54	5.0 (2.0)	15.0/pair ^b (6.1)	F to B: 300 B to F: 1000

^a Distance animal would travel from outer edge of one habitat to inner edge of the other; 1 m = 3.281 feet.

^b Smaller range during breeding associated with higher reproductive success.

Results and Discussion

Land use/land cover. The majority of the Chico Creek Watershed is currently undeveloped and covered by forest classes less than 60 years old (Tables 1&4, Appendix A) as a result of active commercial timber harvest (KCD CD 2003). Mature conifer and tall mixed forest occur as small patches of a few hectares in size or less. Development is concentrated at the eastern edge of the watershed adjacent to the city of Bremerton and stretches northwest toward Wildcat Lake, which is surrounded by homes.

Future Landscapes. Under the Planned Trend scenario development on the eastern edge of the watershed increases in size and density. Intensive rural development creates a "Swiss cheese" effect with habitat occurring in small patches (Appendix B) relative to current conditions (Appendix A). The "no harvest" assumption on 50% of parcels over 10 acres resulted in a significant increase in the amount of mature conifer; the present landscape is nearly devoid of this forest type (Table 4). The young conifer class dominated remaining classes, which mainly occur as scattered patches. While the amount of mature conifer forest in the Planned Trend is attractive, the reality of achieving this condition in the near-term (50 years) rests heavily on the assumption that half of residential landowners will not cut their trees. An underlying assumption is that parcels are developed without the prior removal of existing timber. If this latter assumption

were violated the time required for trees to reach a mature age would double and habitat would be unavailable to species needing this forest type in the intervening time period. In the event that trees are removed prior to parcel development there is the added assumption that either natural regeneration or replanting of native trees would take place. The number and complexity of these assumptions greatly reduces the likelihood that mature conifer forest would occur to the extent portrayed in the Planned Trend. There is considerably less development in rural parts of the Conservation and Moderate scenarios, with individual houses randomly placed. These scenarios are more likely to be consistent with the initial assumption that half of landowners would allow their trees to grow. Fragmentation of forestlands, to the extent it occurs in the Planned Trend, would be likely to result in an increased presence of exotic plants and animals (Schwartz 1997). Interactions with exotic species and habitat loss are among the leading causes of endangerment for species listed as threatened or endangered under the Endangered Species Act (Czech and Krausman 1997). These conditions are a likely outcome of the Planned Trend landscape.

The assumption that large blocks of forest would remain in commercial timber harvest results in less mature conifer forest in the Conservation scenario (Appendix C) than in the Planned Trend (appendix B), but more than under current conditions (Table 4). Under the Conservation scenario high-density development in the eastern part of the watershed and around Wildcat Lake combined with less development in forested parts of the watershed resulted in 1) more large habitat patches 2) more suitable habitat, and 3) more habitat between large patches for all species except great blue heron and downy woodpecker relative to the Planned Trend.

The Moderate scenario is similar to the Conservation scenario in the amount and distribution of habitat types (Table 4, Appendix C&D) because development was reduced in rural forests and remaining forestlands were managed for timber. The two wildlife corridors increase effective patch size by maintaining connectivity between large habitat patches. For example the Kitsap Lake/Gorst Wildlife Corridor maintains the link between upland habitat and wetlands at the south end of Kitsap Lake. There are a larger number of developed parcels in rural forestlands under the Moderate scenario compared to the Conservation scenario. Failure to transfer development rights away from forestlands would increase fragmentation and similarities with the Planned Trend.

Table 4. Distribution of habitat classes under current conditions and 3 future landscape alternatives expressed as a percent of analysis window [Chico Creek Watershed plus 5,437-ft (1,657-m) buffer]; 1% = 252 ac (102 ha); Kistap County, Washington.

Habitat Classification	Current	Planned Trend	Conservation	Moderate
Mature conifer	4.3	27.2	23.0	21.8
Young conifer	33.5	14.0	18.0	19.0
Low Mixed Conifer/Deciduous	25.8	8.3	9.9	11.2
Tall Mixed Conifer/Deciduous	4.1	2.0	1.4	1.6
Grass/Forb/Bare	5.8	4.7	7.8	7.8
Fully Developed	17.5	34.5	30.4	29.1
Water/wetlands	5.4	5.5	5.2	6.0
Total riparian ^a	3.6	3.8	4.3	3.5
Total upland ^b	69.9	52.4	55.9	57.9

^a Undeveloped stream habitat only

^b Forest and grass/forb/bare categories only.

The heterogeneous landscape that results from a variety of forest classes and land uses under the Conservation and Moderate scenarios could correlate with greater species diversity, however species diversity alone is not inherently beneficial (see Noss and Cooperrider 1994; Soule and Teborgh 1999 for discussion). Also, less fragmentation occurs at the landscape scale because development is more concentrated than in the Planned Trend. The application of riparian forest buffers (Appendix C&D; dark mottling particularly in the southwest part of the watershed) suggests that a large tree and snag component would be well distributed across lands managed for timber harvest. This may not create the large patch conditions attractive to species such as the marbled murrelet or spotted owl (Hamer and Nelson 1995; Perkins et al. 1997; Smith et al. 1997), but could add significantly to the vertical structure and coarse woody debris in some managed stands, and provide necessary breeding and resting cover for many vertebrates such as western toads, terrestrial salamanders, *Myotis* bats, tree squirrels, woodpeckers, swifts, owls and other birds, as well as numerous invertebrates.

Species models. Species-habitat maps illustrate the level at which habitat patches contribute to (or fail to meet) home range requirements under current conditions and future alternatives (Appendices E-J). Habitat quantity and quality is summarized by species (Fig. 2). Landscape changes that applied to nearly all species under all future alternatives regardless of habitat association include: 1) a decrease in the total amount of habitat available (Table 4); 2) an increase in fragmentation (i.e. an increase in the number of patches with a corresponding decrease in patch size; and 3) a decrease in habitat quality resulting from loss of primary breeding and foraging habitat. However, individual species responses are mixed due to the diverse life history needs of the species we chose to model; examples are addressed in greater detail below.

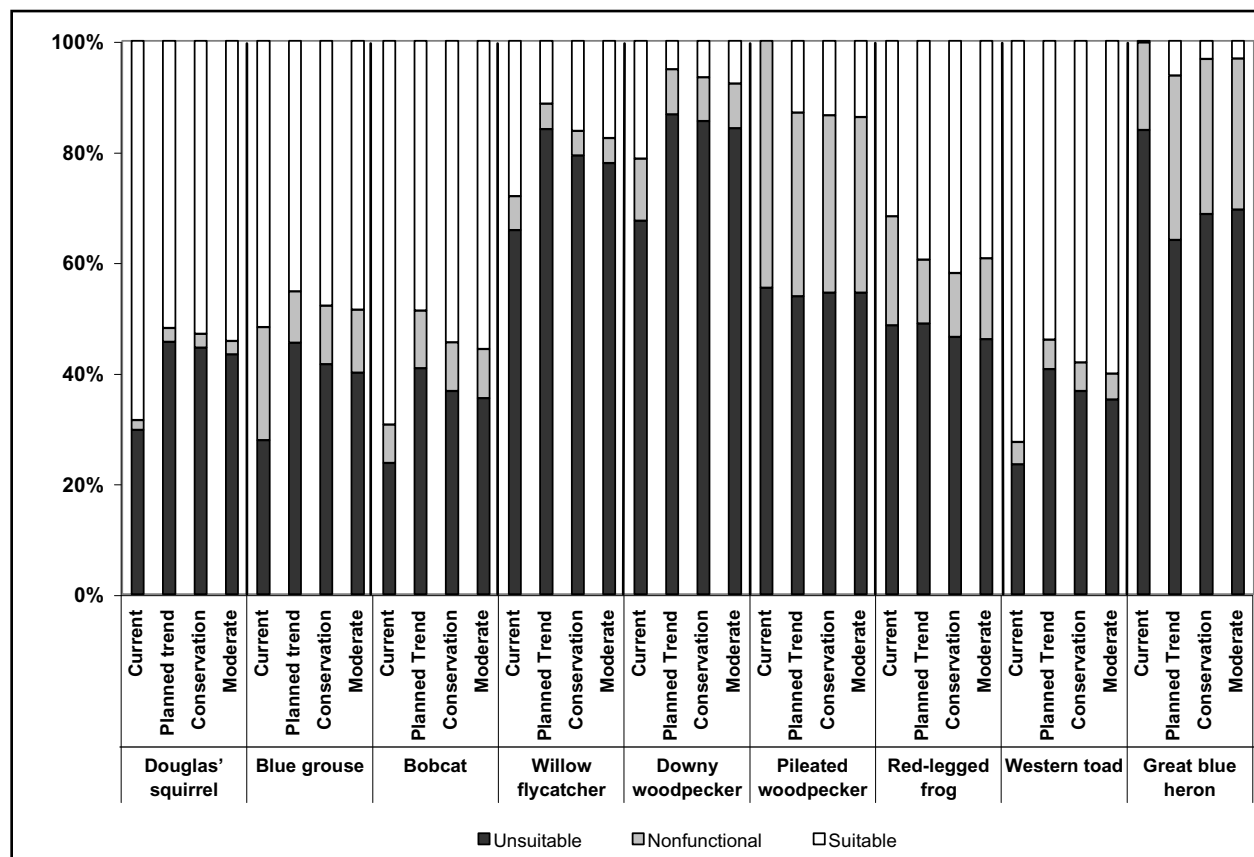


Figure 2. Habitat availability for species modeled in and around the Chico Creek Watershed under current conditions and 3 alternative future landscapes. Unsuitable indicates land cover is not used by the species; nonfunctional indicates correct land cover type but patches too small to be suitable; suitable indicates appropriate habitat in sufficient amounts to function at the home range level. Units are in acres.

Blue grouse use the field and forest edge for breeding, and winter in conifer forest at higher elevations (Irwin et al. 1989; Sopuck and Zwicker 1992). A mosaic of small openings is beneficial to this species, but large openings, such as those that occur presently become nonfunctional (Appendix E). Small forest patches such as those in the Planned Trend appear to lack the juxtaposition of habitats used for breeding. Longer timber rotations and select-cut harvest strategies like those on the Bremerton Municipal Watershed produce better wintering habitat; reforestation practices that emphasize high density replanting, herbicide applications, and fertilization reduce use by blue grouse due to rapid closure of the tree canopy (Rodrick and Milner 1991).

Bobcats have large area needs and use all available habitat to some extent (Yengoyan 1995). Under the Planned Trend, rural housing densities are low enough that suitable bobcat habitat and rural housing are intertwined (Appendix F); increasing the opportunity for human-wildlife conflict would likely be detrimental to both sides (S. Pozzanghera, Washington Department of Fish and Wildlife, pers. comm.). Limited habitat opportunities exist away from human settlements suggesting these animals would have few alternatives. Retaining large blocks of habitat separate from residential areas and concentrating remaining development as in the Conservation and Moderate scenarios would reduce the potential for conflict. Bobcats are similar to coyotes, cougars and bears in their use of habitat.

Potential habitat for the downy woodpecker is reduced under all future conditions (Appendix G) due to their association with deciduous trees, which decline as conifer forest regenerates (Franklin and Dyrness 1973). The Forest and Fish riparian harvest rules in Washington also favor conifer-dominated forest, which are assumed to be the presettlement composition. If true, this species may currently enjoy a broader distribution than it would have historically. Because downy woodpeckers search for insects on small diameter snags and dead branches (Jackson and Ouellet 2002), this species may be conserved relatively easily in suburban and rural areas if landowners retained these features of the natural landscape.

Pileated woodpeckers need large blocks of habitat (Table 3) rich in large snags for breeding (Aubry and Raley 2002). If stated assumptions hold true (i.e., only half of residential landowners cut their trees), our projections suggest that habitat conditions could improve for this species in the future (Appendix H), although site occupancy is ultimately tied to densities of snags and downed logs (Aubry and Raley 2002). Gains in breeding habitat are most pronounced in the Planned Trend scenario, but the Conservation and Moderate scenarios offer breeding patches that are interspersed with blocks of foraging habitat; this arrangement may provide connectivity that could aid in the dispersal of young.

The red-legged frog and the western toad exhibit opposite responses to future alternatives (Fig. 2), primarily due to some red-legged frog habitat moving from nonfunctioning to suitable in response to increases in mature conifer in the uplands. Retaining land in forestry as occurs in the Conservation and Moderate scenarios (Appendix C-D) limits fragmentation, which appears to improve associated riparian conditions for red-legged frog (Appendix I). This factor could contribute to habitat quality, particularly for breeding. Aubry (1997) captured red-legged frogs only on relatively flat sites at least 500 m from permanent ponds. Much of the southwest part of the Chico Watershed is comprised of slopes that rise steeply toward Gold Mountain (1500 m elevation) on the west edge of the watershed (Roberts 2003).

Breeding habitat situated close to high-quality foraging habitat contributes to nest success for great blue herons, although birds will travel over larger areas (Gibbs and Kinkel 1997; Kelsall 1991). An increase in breeding habitat of potential importance to herons is suggested by the Planned Trend (Appendix J), which results from the assumption that half of residential landowners allow their trees to grow. In addition to the caveats already mentioned, fragmentation and development pressure in surrounding areas would also play an important role in the likelihood that this scenario would actually occur (Carlson and McClean 1996; Gibbs and Kinkel 1997). Fewer breeding patches were deemed suitable under the Conservation and Moderate scenarios, but limited development around some patches classified as nonfunctional could make them attractive with only a slight increase in foraging distance (Appendix B-D).

Summary and Management Recommendations

The degree to which species are impacted by habitat loss and degradation is a function of both life history constraints and the type of habitat lost. This exercise demonstrates that in the face of increasing development there are limited opportunities to retain relatively large habitat patches, which can play an important role in the conservation of native species (Noss and Cooperrider 1994; Soule and Ternorh 1999). However, when such patches are maintained they function in a variety of important ways to sustain terrestrial wildlife species. The alternative futures process also points out that the details of land management can also significantly affect the level of impact that can be expected from future development. Concentrating development by the transfer or sale of building rights, clustering new houses, planning for the careful placement of roads and utility corridors, restoring habitat, and conserving native vegetation can increase the amount of habitat available and enhance its value for wildlife by increasing effect patch size, retaining more high-quality habitat, and reducing detrimental human-wildlife interactions. Such actions can also have the added benefit of reducing infrastructure and other human-related expenses. The addition of wildlife corridors has many benefits, in this case connecting large habitat patches and insuring that lakeshores do not become exclusively private property at the expense of the public and the wealth of other animals that use these habitats. This development pattern impacts breeding waterbirds by destroying and degrading habitat, which causes species such as the common loon, to abandon the site or select a marginal location, which compromises their reproductive success (Richardson et al. 2000).

Additional analyses that would provide more detailed information on landscape and home-range level differences in future scenarios are the calculation of average patch size, number of suitable patches, and mean habitat density at the level of the individual species and for the landscape as a whole. Sensitivity analysis on issues such as patch size for great blue heron breeding locations would also provide a better gauge of model accuracy. In our analysis tall mixed forest was poorly represented in future scenarios because we were unable to model for regeneration of this forest type. Additional efforts to better simulate forest regeneration and increase the application of the model and improve the potential for more meaningful results.

Collectively, this suite of models likely underestimates impacts of future development alternatives on most wildlife species for 3 reasons. First, the influence of roads has not been considered. Roads act as barriers to movement and are sources of fragmentation and mortality (Marzluff and Sallabanks 1998; Schwartz 1997). Second, pets function as well-fed, healthy predators free of disease, which occur in unnaturally high concentrations (Link 1999). Third, other edge-related affects that favor exotic species and those well adapted to human conditions (e.g. starlings, cowbirds, crows, skunks, and opossums) were not factored in either. These species may depress populations of native birds and small mammals by occupying limited nest sites and feeding on eggs and nestlings (Marzluff and Sallabanks 1998; Schwartz 1997). While details such as these are important, they are not beyond consideration in determining what and where we should focus our conservation efforts (Noss and Cooperrider 1994; Soule and Terborgh 1999)

The value of the alternative futures approach is its' power as a tool of the human imagination; the same imagination put people in outer space, altered the flow of even the largest rivers, and created the mechanisms for broad-scale protection that gave us our national parks, wildlife refuges, and public forests. Through the alternative futures process, the application of careful thought, planning, and analysis can be used to direct future human actions, which could go a long way toward creating a world in which human health and ecosystem health experience a common future.

Acknowledgments

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





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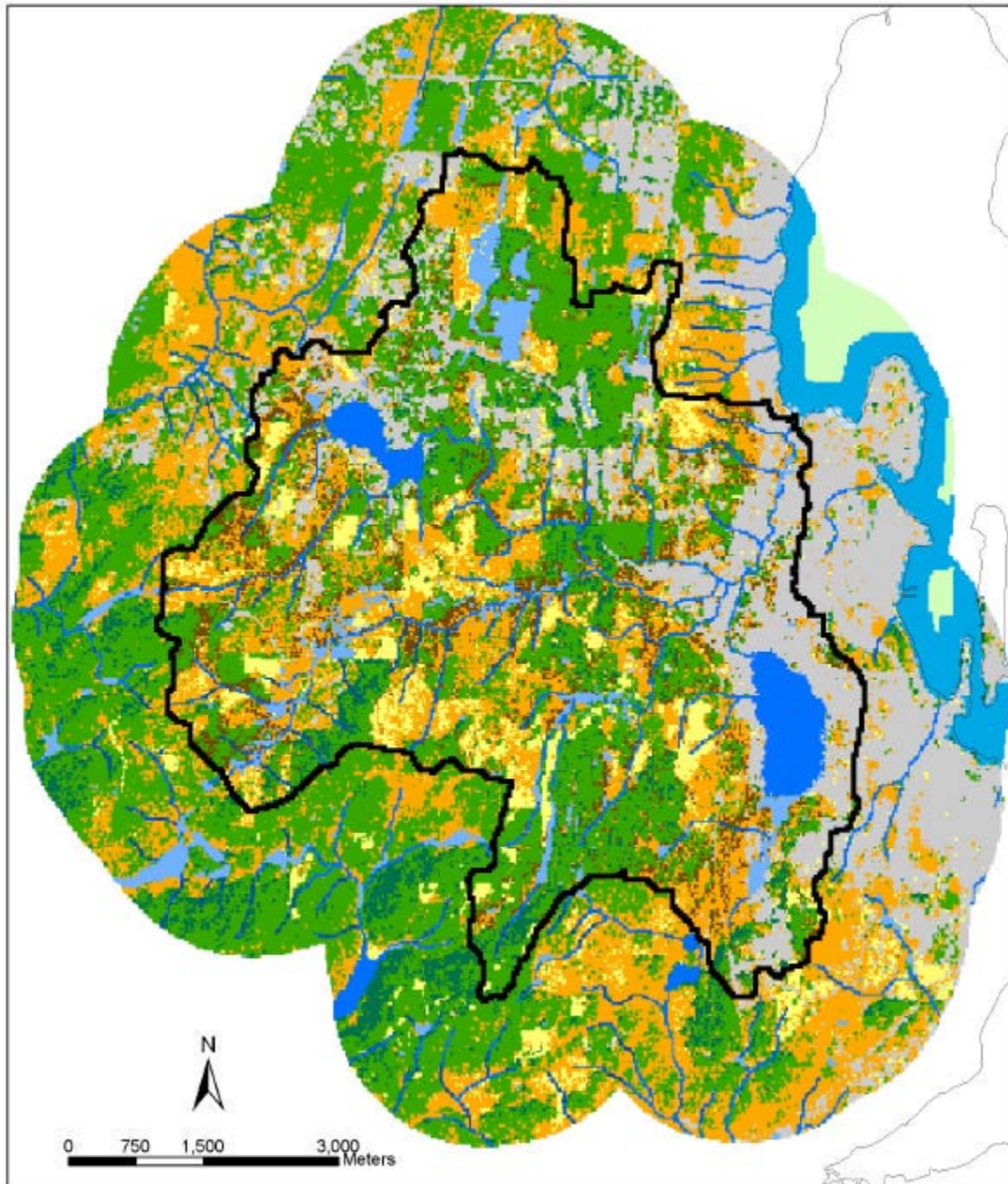
Appendices

Legend of Land Use/Land Cover Classes for Maps of the Chico Creek Watershed, Kitsap County, Washington (Applies to appendices A-D).

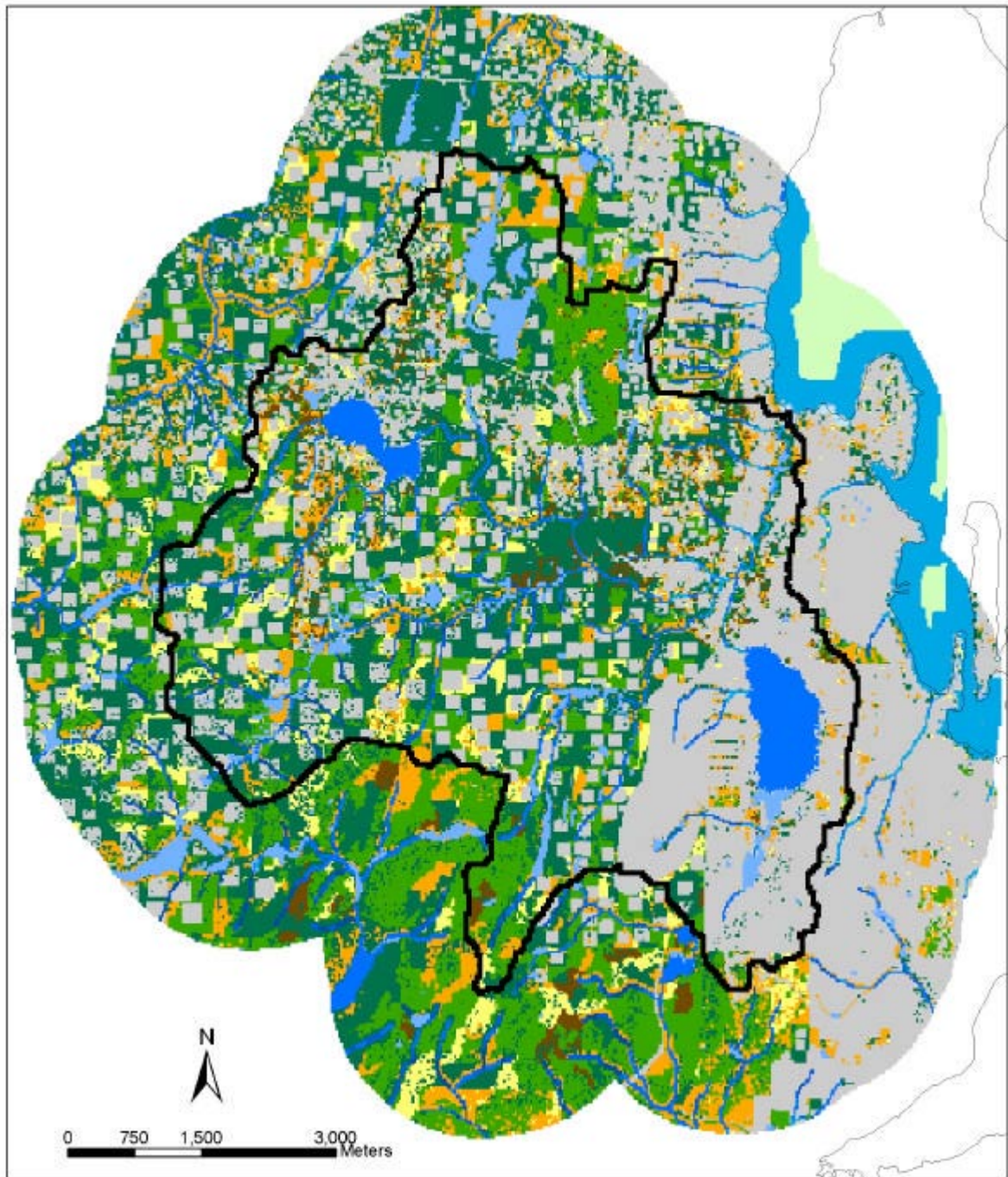
Habitat type

	Late conifer
	Mid/Early conifer
	Low mixed
	High mixed
	Grass-forb
	Fresh marsh
	Salt marsh
	Agriculture
	Fully Developed
	Lakes/Ponds
	Marine
	Stream gradient 1-10%
	Far-shore marine
	Stream gradient 11-20%
	Stream gradient 21%+

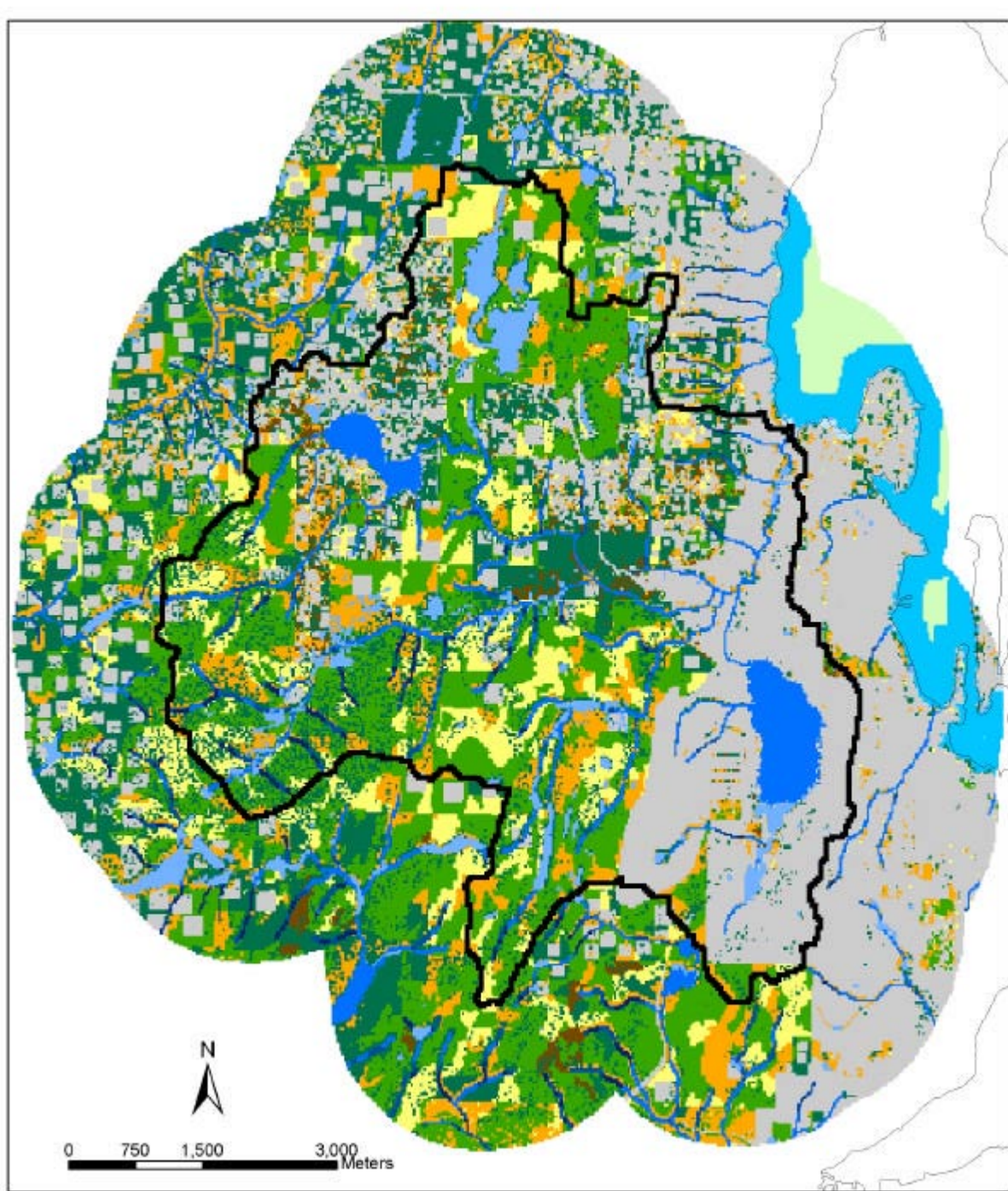
Appendix A. Model of current land cover conditions in the Chico Creek Watershed (black line) in Kitsap County, Washington; includes a 5,437-ft (1,657-m) buffer. Attached legend applies to all land cover models (Appendix A-D).



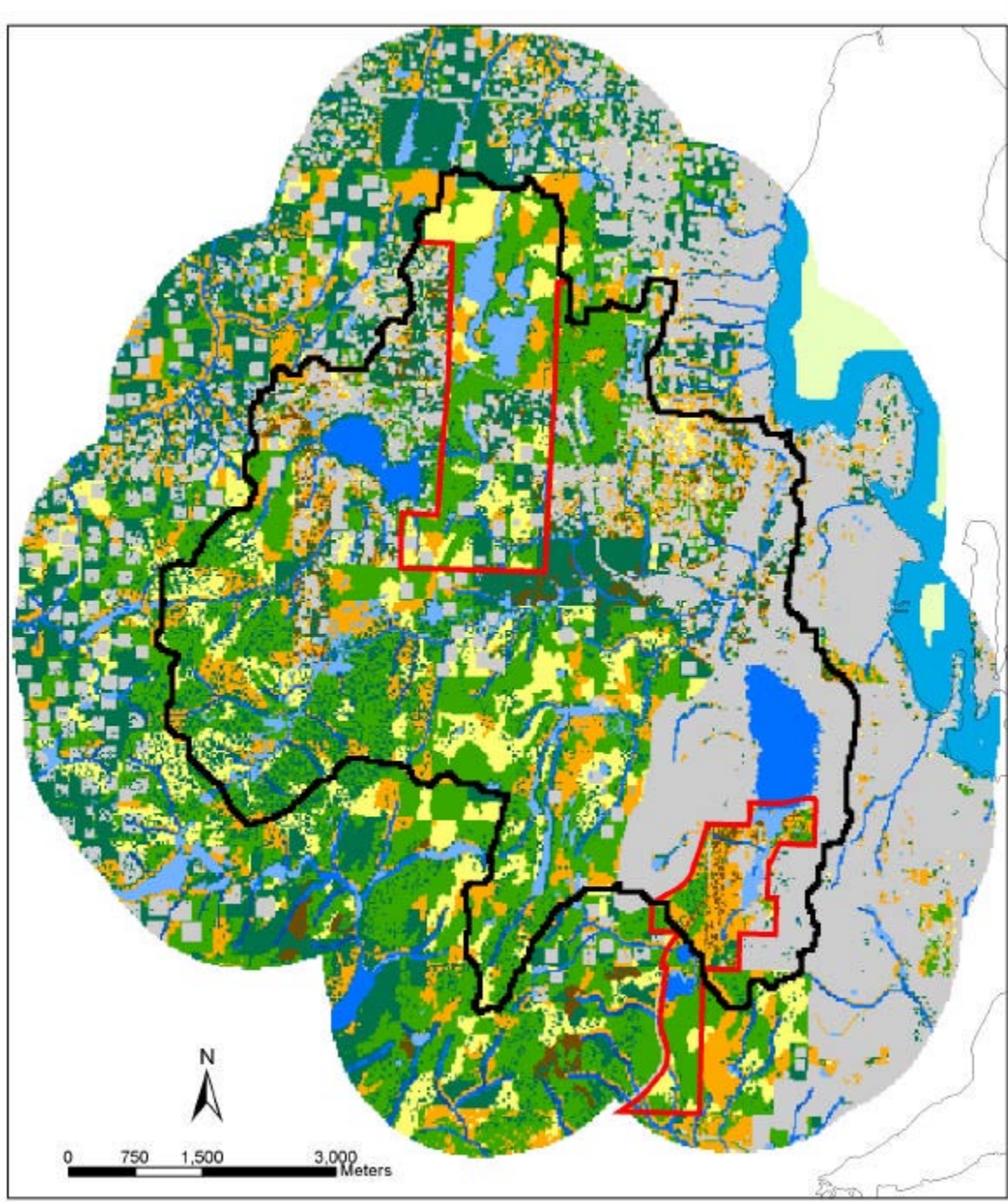
Appendix B. Model of potential land cover resulting from full build-out of the Planned Trend scenario in the Chico Creek Watershed (black line) in Kitsap County, Washington; includes a 5,437-ft (1,657-m) buffer. Model is based on full build-out of the Kitsap County Comprehensive Plan.



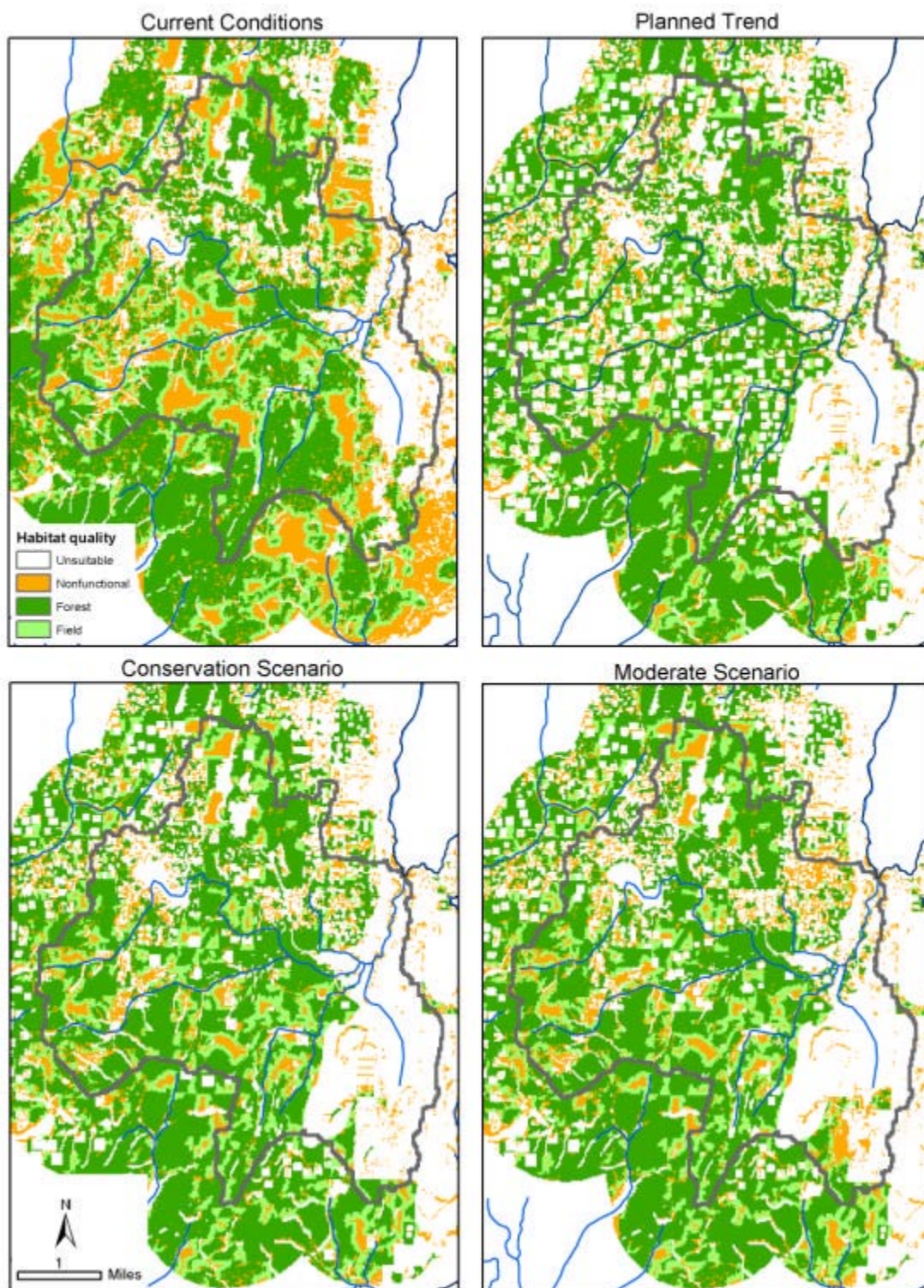
Appendix C. Model of potential land cover resulting from the Conservation scenario in the Chico Creek Watershed (black line) in Kitsap County, Washington; includes a 5,437-ft (1,657-m) buffer. See text for details.



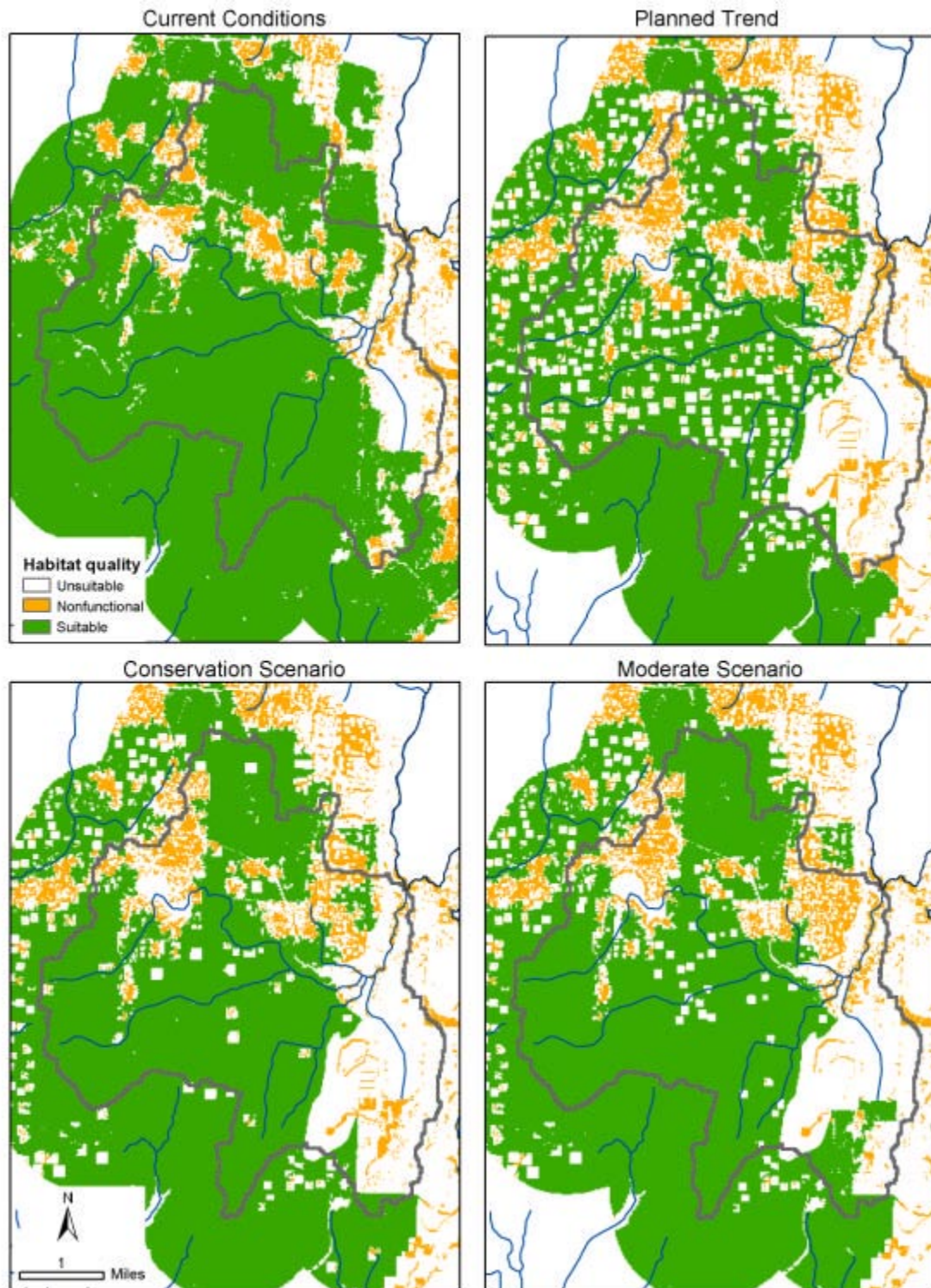
Appendix D. Model of potential land cover resulting from the Moderate scenario in the Chico Creek Watershed (black line) in Kitsap County, Washington; includes a 5,437-ft (1,657-m) buffer. Wildlife corridors are indicated by red line; see text for details.



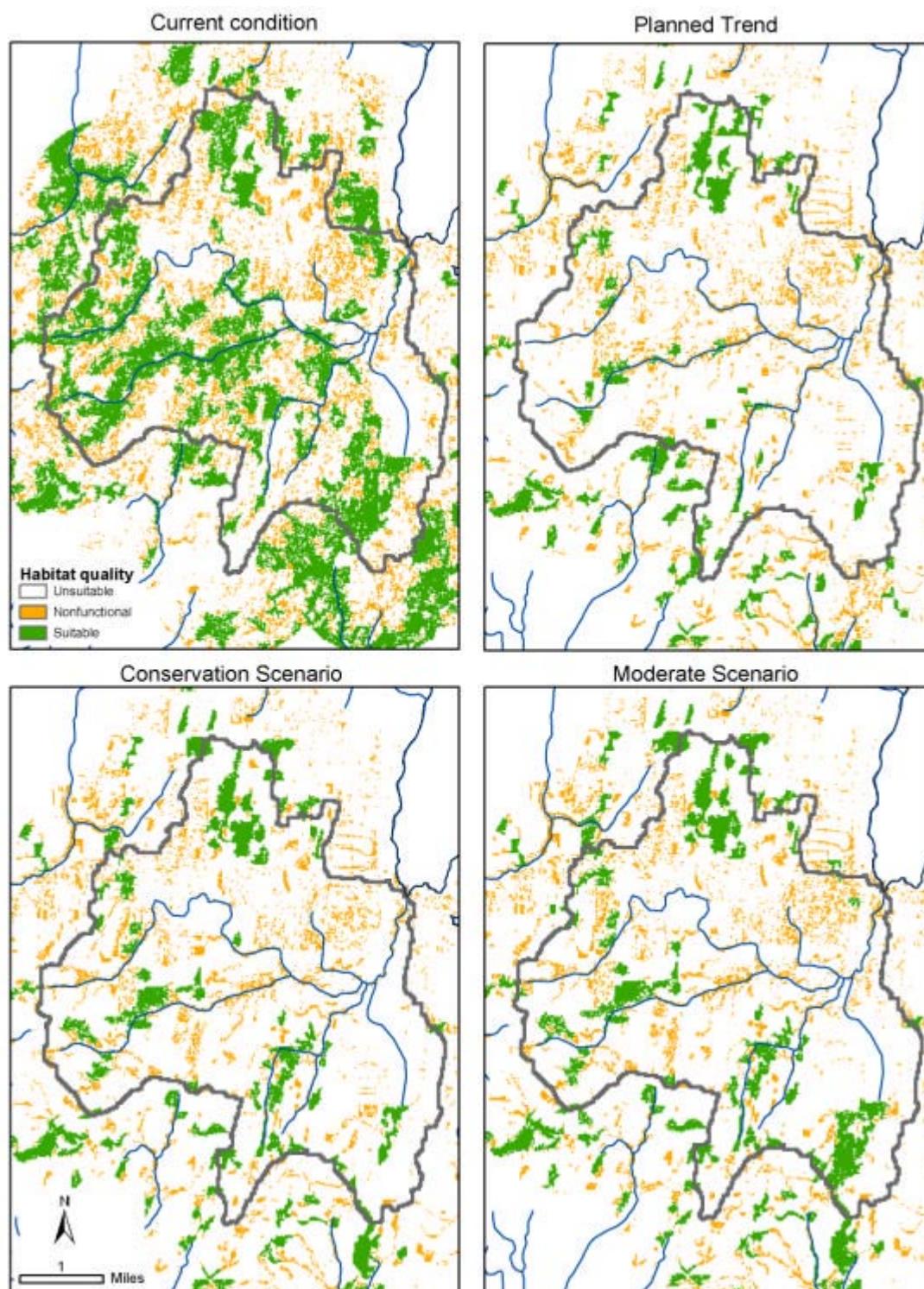
Appendix E. Model of potential habitat value for blue grouse in the Chico Creek Watershed, in Kitsap County, Washington, under current conditions and 3 future land cover alternatives. See Table 3 for model parameters. Unsuitable indicates land cover not used by the species; nonfunctional indicates correct land cover type but patches too small to be used; forest and field indicate appropriate habitat in sufficient amounts to function at the home range level.



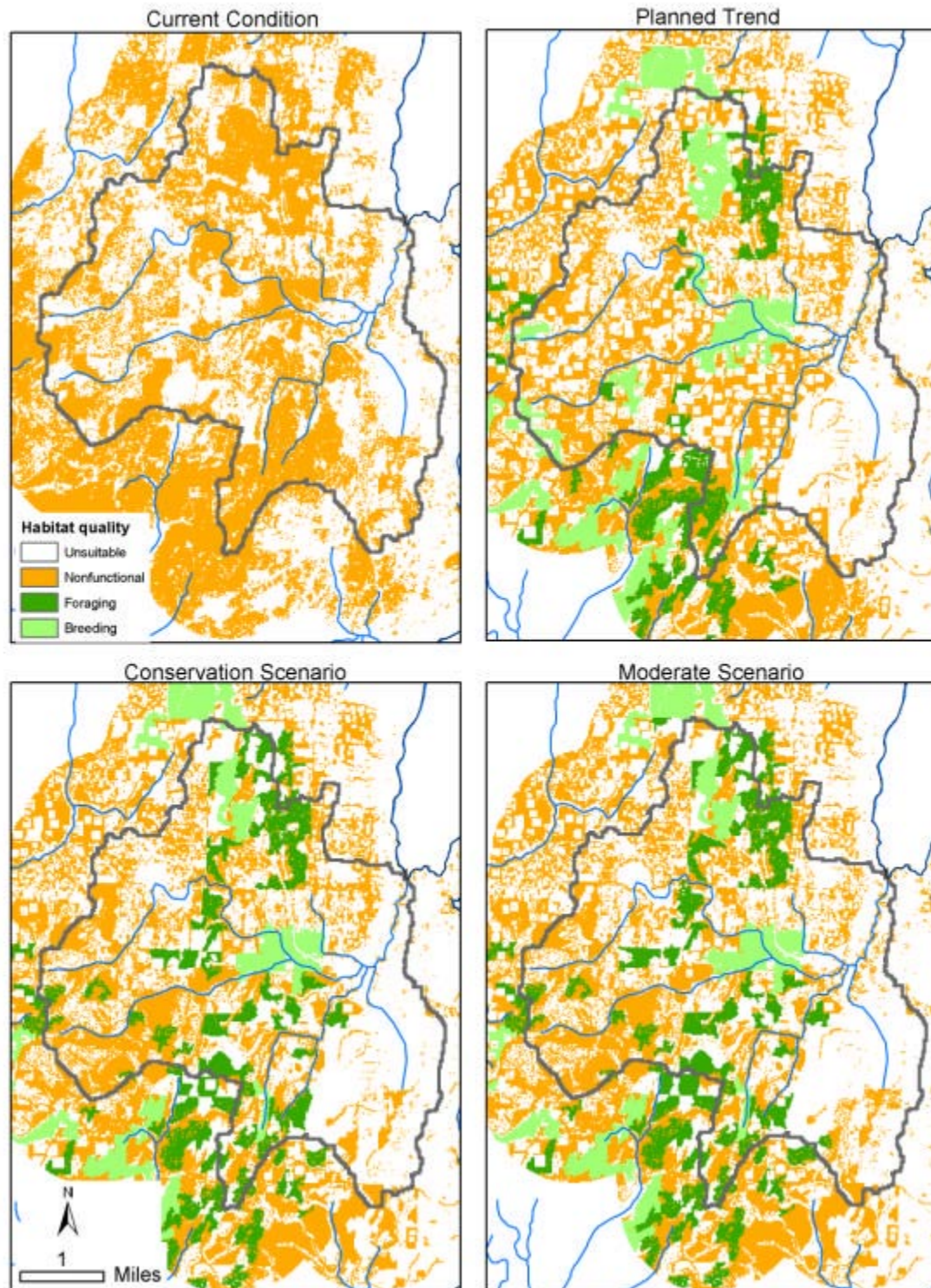
Appendix F. Model of potential habitat value for bobcat in the Chico Creek Watershed, in Kitsap County, Washington, under current conditions and 3 future land cover alternatives. See Table 3 for model parameters. Unsuitable indicates land cover not used by the species; nonfunctional indicates correct land cover type but patches too small to be suitable; suitable indicates appropriate habitat in sufficient amounts to function at the home range level.



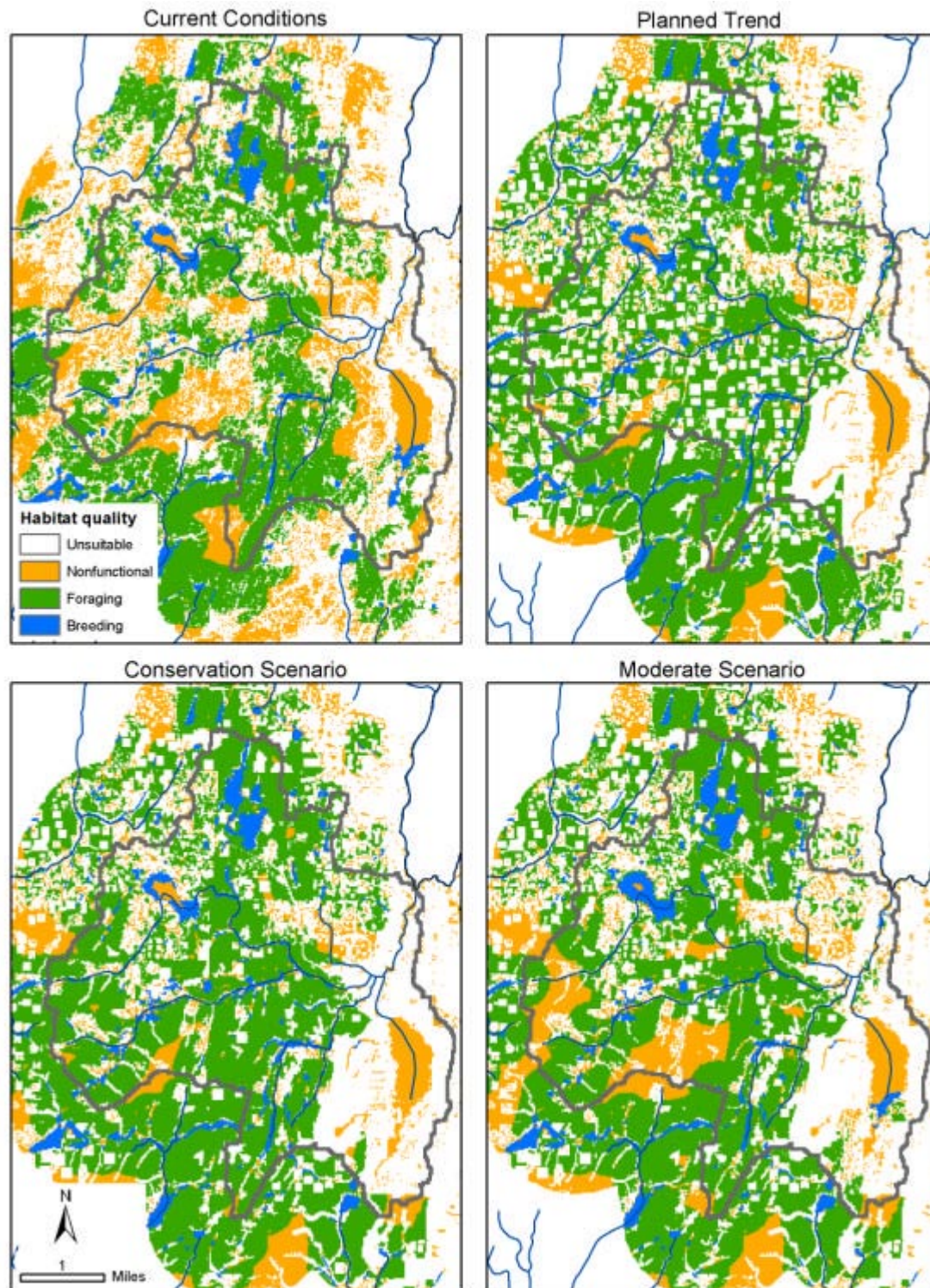
Appendix G. Model of potential habitat value for downy woodpecker in the Chico Creek Watershed, in Kitsap County, Washington, under current conditions and 3 future land cover alternatives. See Table 3 for model parameters. Unsuitable indicates land cover not used by the species; nonfunctional indicates correct land cover type but patches too small to be suitable; suitable indicates appropriate habitat in sufficient amounts to function at the home range level.



Appendix H. Model of potential habitat value for pileated woodpecker in the Chico Creek Watershed, in Kitsap County, Washington, under current conditions and 3 future land cover alternatives. See Table 3 for model parameters. Unsuitable indicates land cover not used by the species; nonfunctional indicates correct land cover type but patches too small to be used; breeding and foraging indicates appropriate habitat in sufficient amounts to function at the home range level.



Appendix I. Model of potential habitat value for red-legged frog in the Chico Creek Watershed, in Kitsap County, Washington, under current conditions and 3 future land cover alternatives. See Table 3 for model parameters. Unsuitable indicates land cover not used by the species; nonfunctional indicates correct land cover type but patches too small to be used; breeding and foraging indicates appropriate habitat in sufficient amounts to function at the home range level.



Appendix J. Model of potential habitat value for great-blue heron in the Chico Creek Watershed, in Kitsap County, Washington, under current conditions and 3 future land cover alternatives. See Table 3 for model parameters. Unsuitable indicates land cover not used by the species; nonfunctional indicates correct land cover type but patches too small to be used; breeding and foraging indicates appropriate habitat in sufficient amounts to function at the home range level.

